1977

Feeding Ecology of Black Sea Bass Centropristis striata on an Artificial Reef off Virginia (Perciforms: Serranidae)

Ping K. Chee
Old Dominion University

FEEDING ECOLOGY OF BLACK SEA BASS

CENTROPRISTIS STRIATA ON AN ARTIFICIAL REEF OFF

VIRGINIA. (PERCIFORMES: SERRANIDAE)

Ping K. Chee

A thesis presented in partial fulfillment
of the requirements for the Degree of

MASTER OF SCIENCE

INSTITUTE OF OCEANOGRAPHY
OLD DOMINION UNIVERSITY

Supervisory Committee

(Director) Ray S. Birdsong

Ronald E. Johnson

Anthony Provenzano

John Merriner

ABSTRACT

FEEDING ECOLOGY OF BLACK SEA BASS
CENTROPRISTIS STRIATA ON AN ARTIFICIAL REEF OFF
VIRGINIA. (PERCIFORMES: SERRANIDAE)

Ping K. Chee
Old Dominion University, 1977

The feeding ecology of the black sea bass, Centropristis striata, associated with artificial reefs shows seasonal and size-related changes. Monthly collections totalling 520 black sea bass taken from an artificial reef near the Chesapeake Light Tower, Virginia, between August 1975 and May 1976, were analyzed for food habits as revealed by number, volume, frequency of occurrence and a modified Index of Relative Importance.

The black sea bass feeds on the artificial reef as well as the adjacent areas. When food was abundant on the reef, food items from the reef and the surrounding area were consumed. Upon depletion of the food resource on the reef, the black sea bass resorted to feeding primarily from the areas adjacent to the artificial reef. The four overall predominant foods were Ensis directus (IRI'=910), Pagurus spp. (IRI'=7299), Cancer irroratus (IRI'=601) and Mytilus edulis (IRI'=332). The feeding ecology of the black sea bass on the artificial reef suggests that they are attracted to the reef primarily because of the shelter that the reef affords.

ACKNOWLEDGEMENT

I wish to express my gratitude to Dave Waltz, Kathy Schmitz, O. B. Stander, Guy Clark, and Denise Hollomon for their help in the field collection. I am especially grateful to Ernie Beier for enduring the underwater observations in the winter and the crew of the R/V LINWOOD HOLTON for their help during the cruises.

I am most grateful to the members of my committee, Dr. Ray Birdsong, Dr. Anthony Provenzano and Dr. Ronald Johnson for their guidance of my research and their review of the manuscript. I am grateful to Richard Stone of the National Marine Fisheries Service for his suggestions and technical support and to Mike Meier of the Marine Resources Commission for providing the information about the artificial reef. I am also thankful to Dr. John Merriner for his advice and review of the manuscript.

Finally, to my parents I owe a very special debt of gratitude for their support throughout this research.

Table of Contents: continued

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Artificial reefs have been used extensively in recent years to improve the carrying capacity of marine habitats. Large numbers of artificial reefs have been built in California and throughout the Atlantic and Gulf Coasts to improve recreational fishing. Use of artificial reefs in the United States for commercial fishing is increasing.

The two main factors that attract organisms to artificial reef are shelter and food. The reef structures provide shelters from predators and areas of calm water where fishes can conserve energy. Fishes are also attracted to artificial reefs because of the food provided by encrusting organisms. Klima and Wickham (1971) in their study of a mid-water artificial reef suggested the importance of the reef as a spatial reference for fish in an otherwise uniform environment.

The success of artificial reefs in supporting or enhancing growth of marine organisms was reported by Randall (1963), Matthews (1966), and McVey (1970).

Artificial reefs have been built in Virginia's inshore and offshore waters over a number of years. The study site for this research is the largest of these reefs located near the Chesapeake Light Tower, about 14 miles due east of Cape Henry (Fig. 1). The reef was built with more than 150 vessels, most of which are surplus landing craft. The reef is still being added to with structures composed of bales of car tires.

Virginia has an active construction program, but a research program to monitor the effect of existing artificial reefs already in existence has not been initiated.

The black sea bass occurs from Cape Cod, Massachusetts to Cape Kennedy, Florida, (Miller, 1959) and is an important sport and commercial fish in the mid-Atlantic Bight (Musick and Mercer, 1977). Black sea bass are found in "live bottom" areas of the open shelf and shelf edge habitats (Stuhsaker, 1969). These areas are characterized by outcroppings of rock and ancient coral reefs bearing a layer of encrusting invertebrate growth (Cupka, 1972). The artificial reef near the Chesapeake Light Tower, Virginia, successfully duplicates a "live bottom" environment and is an aggregation site for recreational fishermen and divers.

The food and feeding habits of the black sea bass are presented with respect to the food resource available on the reef and the surrounding area, the size of the fish and the water temperature. Other aspects of this research included evaluation of the success of the artificial reefs built to date. The questions that I tried to answer include:

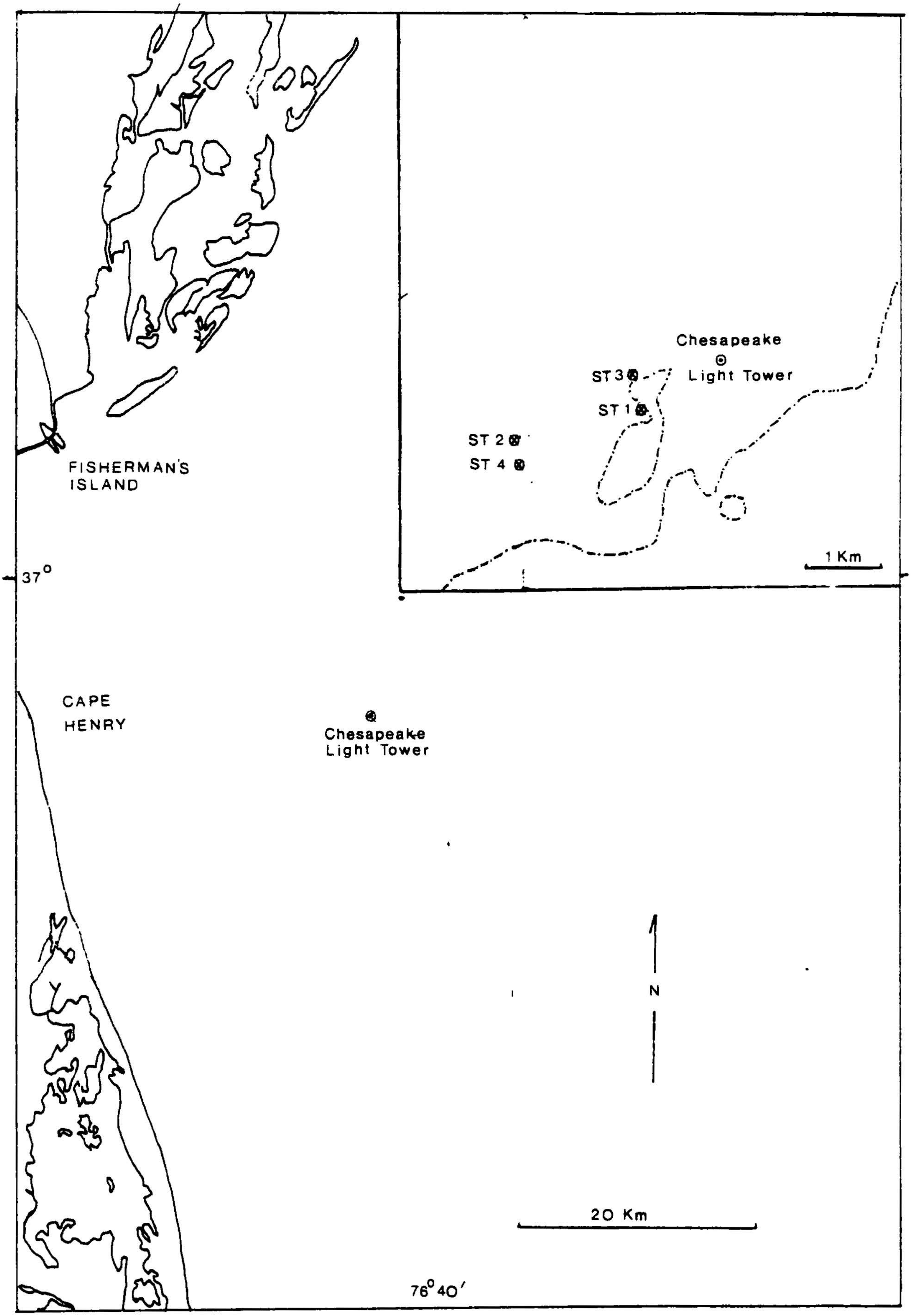
1) Do black sea bass feed on the artificial reef or nearby bottom?

2) Is there a seasonal succession of food resource for the black sea bass on the artificial reef?

3) Is there a seasonal migration of black sea bass on the artificial reef?

4) Is there a size-related feeding of black sea bass on the reef?

Figure 1. Chesapeake Light Tower and the artificial reef structures studied. Insert shows the positions of artificial reef structures ST 1 - ST 4 and with respect to the Chesapeake Light Tower and the 12 meters contour.


Chesapeake
Light Tower
ST 3
ST 1
ST 2
ST 4
1 Km
FISHERMAN'S
ISLAND
37°
CAPE
HENRY
Chesapeake
Light Tower
N
20 Km
76°40′

METHOD

Four reef structures were selected as sampling sites for black sea bass (Table 1). Hook and line sampling of the black sea bass on the four artificial reef structures was carried out at least once a month between August 1975 and May 1976.

Dives of approximately 30 minutes duration were made during each cruise on ST 1 to observe and identify the organisms encrusting the artificial reef and the surrounding areas. The organisms found on the artificial reef were compared with the stomach contents of the black sea bass caught on the artificial reef. During each diving survey, the most abundant potential food organisms on the artificial reef were recorded while swimming once around the structure. A visual estimate of the number of fish was also carried out on the structure ST 1 to determine the relative abundance of the fish associated with the structure. Bottom temperatures were recorded by diver held thermometers for each month during the study.

Two trawls were carried out, once in December and once in May to qualitatively sample the organisms found around the reef diet of the black sea bass.

Food habits of black sea bass were evaluated by the:

1) Volumetric method in which total food volume was determined by displacement of water in a graduated cylinder. After sorting the food items, the percent contribution to the total volume by each food item was determined.

2) Numerical method in which the number of individuals of each type were expressed as a percentage of the total number of food items present in each stomach.
3) Frequency of occurrence method in which each food item in each individual stomach sample was tallied and expressed as a percentage of the total number of stomachs containing food.

A modification of the Index of Relative Importance developed by Pinkas, Oliphant and Iverson (1971) was used to consolidate the three methods used in food item evaluation. The original Index of Relative Importance was calculated by summing the numerical and volumetric percent and multiplying by the frequency of occurrence percent. The modified Index of Relative Importance, which I shall designate IRI', emphasizes percent volume. It is calculated by summing numerical and frequency percent and multiplying by the percent volume. I used the modified Index of Relative Importance (IRI') because I felt that in this study, the percent volume is a better indicator of food items in terms of energetics than either the numerical or frequency percent. Although the IRI' helps overcome the limitations imposed by the numerical, frequency and volumetric method when considered individually, it still does not take into account the nutrition factor. Food items such as bivalves with undigestable shells certainly provide less nutrition than food items such as fish. But in this study, the discrepancy between the IRI' of the important food items and the less important food items was so great that it leaves little doubt that the food items with the larger IRI' provided more nutrition.

Black sea bass were grouped into total length size class of five centimeters; beginning with 10 cm for analysis of feeding by fish size.

Sampling Bias and Data Limitations

The hook and line method used in this study was selective in size and species of fish collected. The hook and line captured mostly black sea bass. Underwater observations revealed that pinfish, tautogs, and small (less than 10 cm in total length) sea bass were present but sampling technique captured mostly black sea bass between 10 and 65 cm in total length. The selective capture of the hook and line method was probably due to the squid that was used as bait and the hook size. Tautogs were captured when crab was used as bait.

Underwater observations also confirmed the relative abundance of the different size classes as shown in Table 2. Most of the black sea bass observed underwater were of the 15-25 cm size class.

The direct observation fish carried out during this study was subjected to errors such as water visibility and the reclusive behavior of some fishes. However, the relative abundance of the black sea bass on the artificial reef can be inferred from the fish estimate carried out on ST 1.

Larger fish samples were collected in August and December (Table 2), because two cruises were made in these two months while only one cruise was carried out in the other months.

The sample was also biased by the sampling period. Important food items in the summer (June and July) were excluded from the samples.

RESULTS

Fishes Captured

From August 1975 through May 1976, a total of 563 fishes (six species) were collected by hook and line and spearing from the artificial reef. The most frequently caught fish was the black sea bass followed by the tautog, *Tautoga onitis* and the pinfish, *Lagodon rhomboides*.

The black sea bass was the most abundant fish by the rod and reel collection method. The number of black sea bass captured each month by 5 cm size class is shown in Table 2.

August and November yielded 69% of the black sea bass, because of better sea condition which allowed more cruises in these months than other months. The overall size range of black sea bass collected was 10-65 cm, with 15-20 cm and 20-25 cm representing 80% of the sample and fishes over 30 cm representing 5%, while fishes over 40 cm were rare (less than 0.6%)(Table 2).

Total Food Items (Fig. 2, Table 3)

The black sea bass swallowed food whole, making identification of undigested food material possible. Empty black sea bass stomachs were common (22.6% of fish examined).

The razor clam, *Ensis directus*, (IRI'=910) was the dominant food item in the stomach of the black sea bass according to the IRI', but was not the most important food item in number, volume or frequency of occurrence, yet it was consistently high in all the three component values (number = 16.0%, volume = 25.2%, frequency = 20.1%).

Hermit crabs (*Pagurus longicarpus* and *Pagurus pollicaris*) were the second most important food item (IRI'=729). They ranked fourth in number (12.8%), first in frequency (27.3%), and third in volume (18.3%).

The rock crab, *Cancer irroratus*, was the third most important food item (IRI'=601). *C. irroratus* ranked sixth in number (7%), fourth in frequency (15.8%) and first in volume (26.2%).

The blue mussel, *Mytilus edulis*, ranked fourth in IRI' (322). *M. edulis* was abundant on the reef from April through August. It may be a more important food source in the summer than indicated by my data (June and July, no samples). As a food item, blue mussels ranked first in percent number (30.5%), third in frequency and ranked fourth in volume (6.6%).

The remaining twenty food items (combined IRI'=44) were far less important than the preceding major food items. Although caprellids were abundant on the reef, the black sea bass did not feed on them very much. Similarly, Gammarid amphipods were abundant on the reef but were not common in the stomachs; however, when present they appeared in large numbers. Other lesser food items found were the crabs *Ovalipes ocellatus* and *Panopeus herbstii* and unidentified fish remains.

August Food Analysis (Fig. 3, Table 4)

One hundred and seventy-nine black sea bass taken in August, included 39 with empty stomachs.

The rock crab was the most important food item (IRI'=947.3); it ranked fourth by number, third in frequency (19.1%) and first in volume (35.1%).

The razor clam ranked second overall (IRI'=807) and was second in number (22.5%); first in frequency (15.1%) and second in volume (21.5%).

Third in importance were hermit crabs (IRI'=598.2). They ranked third in number (14.5%), second in frequency (22.6%), and third in volume (16.2%).

The blue mussel ranked fourth with an IRI' value of 583 and ranked first in numbers (43.8%) and frequency (25.5%), but was low in volume, (8.4%).

Other food items included unidentified teleosts, the mudcrab, *Panopeus herbstii*, and spider crab, *Libinia emarginata*.

September Food Analysis (Fig. 3, Table 5)

Thirty-seven black sea bass stomachs analyzed from September collections included 11 empty stomachs.

Hermit crabs had the highest IRI' (1594), frequency (30.0%) and volume (36%). It was second in number of individuals (14%).

Razor clams ranked second in food items with an IRI' of 954. Razor clams ranked second in both volume (29.3%) and frequency (21.2%). It was third (8%) in number of individuals.

Third most important food item were gammarid amphipods (IRI'=231). They were highest in number of individuals (63%) but ranked low in volume (3.5%) and frequency (3.0%).

Rock crab ranked fourth by IRI' (36). It ranked fourth in frequency (9.1%), fifth in volume (3%) and number (3%).

Blue mussel was found in some stomachs but they were empty shells that were probably ingested while foraging for other food. Although live blue mussels were absent on the reef by September, gammarids were in and on the empty mussel shells.

Figure 2. Number percent, frequency percent, volume percent and index of relative importance (IRI') of the four most important food items of the 520 black sea bass collected from an artificial reef off Virginia between August 1975 and May 1976.

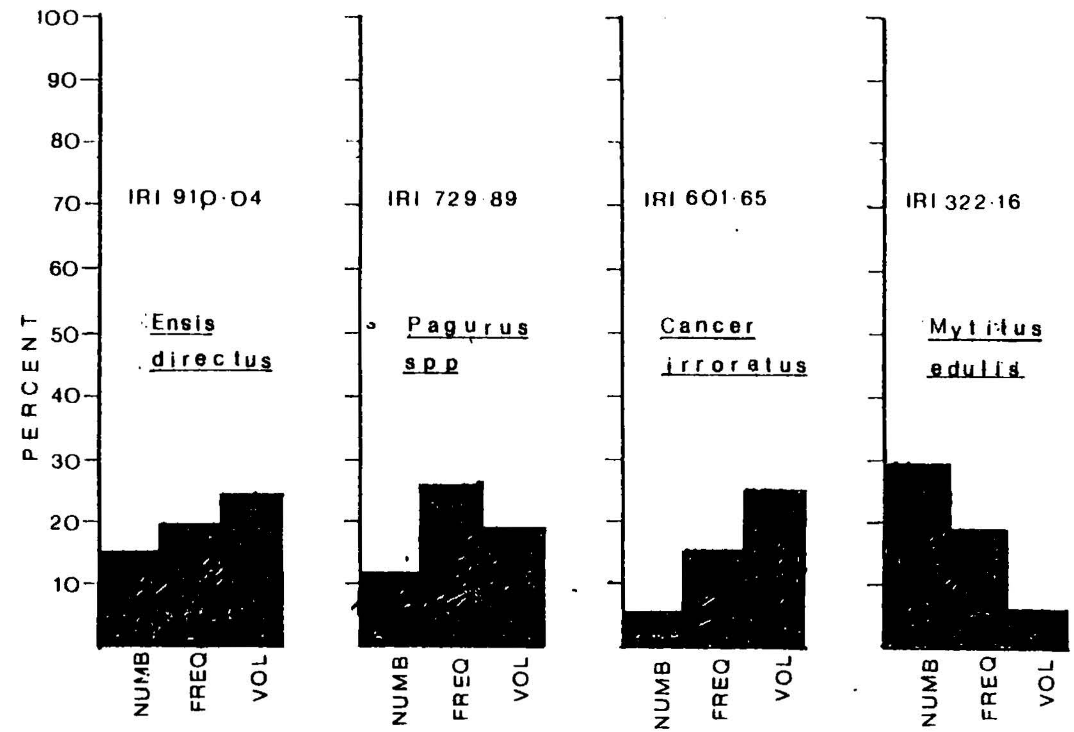
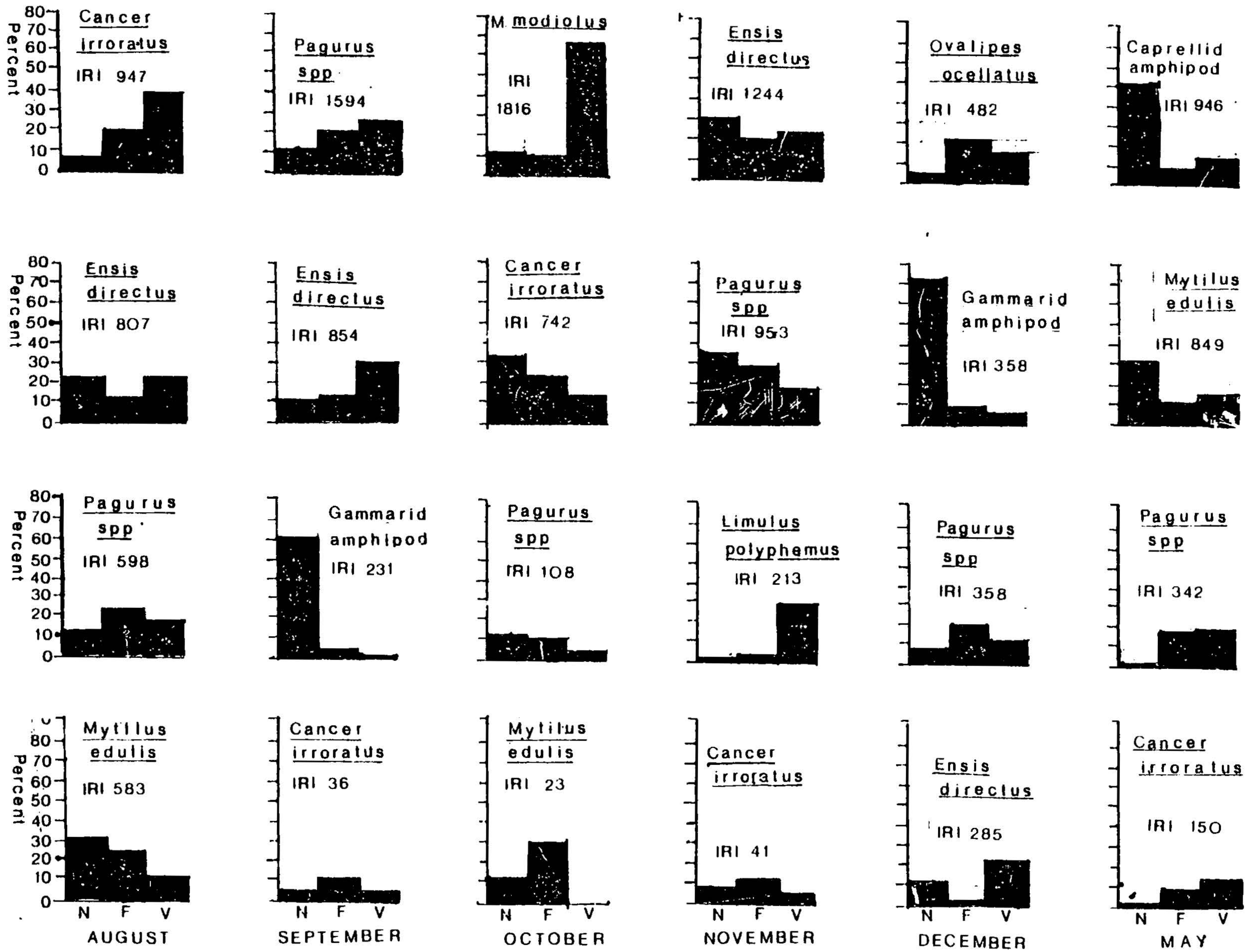

PERCENT
100
90
80
70
60
50
40
30
20
10
IRI 910·04
Ensis directus
IRI 729·89
Pagurus spp
IRI 601·65
Cancer irroratus
IRI 322·16
Mytilus edulis
NUMB
FREQ
VOL

Figure 3. Monthly plots of the four predominant food items of black sea bass by percent number (N), percent frequency (F), percent volume (V) and modified index of relative importance (IRI'). The IRI' are presented in decreasing order of importance from top to bottom.


Percent
0
10
20
30
40
50
60
70
80
Cancer irroratus
IRI 947
Pagurus spp
IRI 1594
M. modiolus
IRI 1816
Ensis directus
IRI 1244
Ovalipes ocellatus
IRI 482
Caprellid amphipod
IRI 946
Ensis directus
IRI 807
Ensis directus
IRI 854
Cancer irroratus
IRI 742
Pagurus spp
IRI 953
Gammarid amphipod
IRI 358
Mytilus edulis
IRI 849
Pagurus spp
IRI 598
Gammarid amphipod
IRI 231
Pagurus spp
IRI 108
Limulus polyphemus
IRI 213
Pagurus spp
IRI 358
Pagurus spp
IRI 342
Mytilus edulis
IRI 583
Cancer irroratus
IRI 36
Mytilus edulis
IRI 23
Cancer irroratus
IRI 41
Ensis directus
IRI 285
Cancer irroratus
IRI 150
N F V
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
MAY

October Food Analysis (Fig. 3, Table 6)

Only 20 black sea bass were collected during October and 12 had empty stomachs. Four different food items were discovered in October, thus the IRI' results were distorted by low sample size.

Modiolus modiolus had by far the largest IRI' value of 1816. *M. modiolus* was found once, but its enormous volume of 76.9% elevated the IRI' value.

Rock crabs ranked second in IRI' value (811). Three (33.3%) rock crabs were found in two black sea bass (frequency = 25%), the volume was 13.9%. If a larger sample had been available, Rock crabs would probably have been the most important food item because *Modiolus modiolus* is a rare food item.

Hermit crabs were found once in a single fish. Shell fragments of blue mussels were also found.

November Food Analysis (Fig. 3, Table 7)

One hundred and seventy-nine stomachs were collected for November and 66 were found empty. Razor clam with an IRI' of 7244 was the most important food item, it was second most important in number (21.1%), frequency (21.9%) and volume (24.3%).

Hermit crabs ranked second with an IRI' of 953, it had the largest number of individuals (30.5%), the greatest frequency (27.5%) and the third largest volume (16.4%).

A food item not found in the other months was the third most important in November. Fragments of the horseshoe crab, *Limulus polyphemus*, was found with IRI' value of 213. Four appendages of the horseshoe crab were found in four different fishes, giving a number and frequency value of 2.8% and 4.4%, respectively. The elevated IRI' value of *L.*

polyphemus was the result of its largest total volume (29.7%) of any food item for the month.

Rock crab ranked fourth in the IRI' with a relatively small value of 41. It had a number value of 6.4%, frequency value of 7.7% and a volume of 3.0%. Other crabs found in November include the portunid crabs, Ovalipes ocellatus and Callinectes sapidus. Traces of blue mussels were also found.

December Food Analysis (Fig. 3, Table 8)

Seventy-two black sea bass were collected in December and 35 empty stomachs were found. The food item with the largest IRI' value of 482 is the Calico crab, Ovalipes ocellatus, which was first noticed among the food items in November. The calico crab ranked fourth in number with a value of 2.1%. Calico crab ranked first in frequency (24.1%) and third in volume (18.4%).

Gammarid amphipod ranked second in IRI' (358). It was by far the largest number of individual food item with a value of 72.1%, and it ranked second in frequency (6.9%) and fifth in volume (4.5%).

Hermit crabs were the third most important food item with an IRI' value of 358. The hermit crabs had a value of 5.7% in number of individuals which was third in importance and a high frequency of occurrence of 24.1% which ranked it in first place with the calico crab. It ranked fourth in volume (12%).

Razor clam ranked fourth in the IRI' (285), second in number of individuals (10.3%), but was found in only one fish for the month, giving a frequency value of 3.5%. It ranked first in volume with a value of 20.2%. The mantis shrimp, Squilla empusa, was found only once in this study. A single unidentified teleost, a badly decomposed goby were also found in December, and traces of blue mussel shells.

May Food Analysis (Fig. 3, Table 9)

Thirty-three black sea bass stomachs were examined in May and 11 were empty. Caprellid amphipods were the most important food item found, with an IRI' of 946. It was the most individual food item found (53.1%) and ranked third in frequency of occurrence. The caprellids were fourth in volume of food items with a value of 15.3%.

An IRI' value of 849 ranked the blue mussel second in importance; it ranked second in the number of individual food item (35.2%); second in frequency of occurrence (13%) and volume (17.6%).

The hermit crabs were third in IRI' standing with a value of 342. The hermit crabs ranked fifth in the number of individual food item with a value of 1.3%, were the most frequently occurring food item (18.4%) and had the largest volume (18.4%).

The fourth ranking food item is the rock crab with an IRI' value of 150. Rock crab had the sixth greatest number of individuals (0.9%); it ranked third with two other food items in frequency of occurrence (9%) and ranked third in volume with a value of 15.6%.

Other food items consumed in May include the mudcrab, *Panopeus herbstii*; a squid, *Loligo peali*; the razor clam, *Ensis directus*; a gammarid, *Melita dentata*; and an unidentified teleost.

Size Class Food Analysis

Two hundred and forty-five black sea bass of the size class 15-20 cm were collected and 90 empty stomachs were found (Table 11). Feeding habits of this size class and those of the next two larger size classes (20-25 cm and 25-30 cm) were quite similar. All had the same food items of greatest IRI' value: razor clams, hermit crabs, rock crabs, and blue mussels. In the 15-20 cm size class, razor clam with the greatest IRI' value of 990 also had the largest volume (30.3%), it ranked second in number (8.2%) and first in frequency (19.5%).

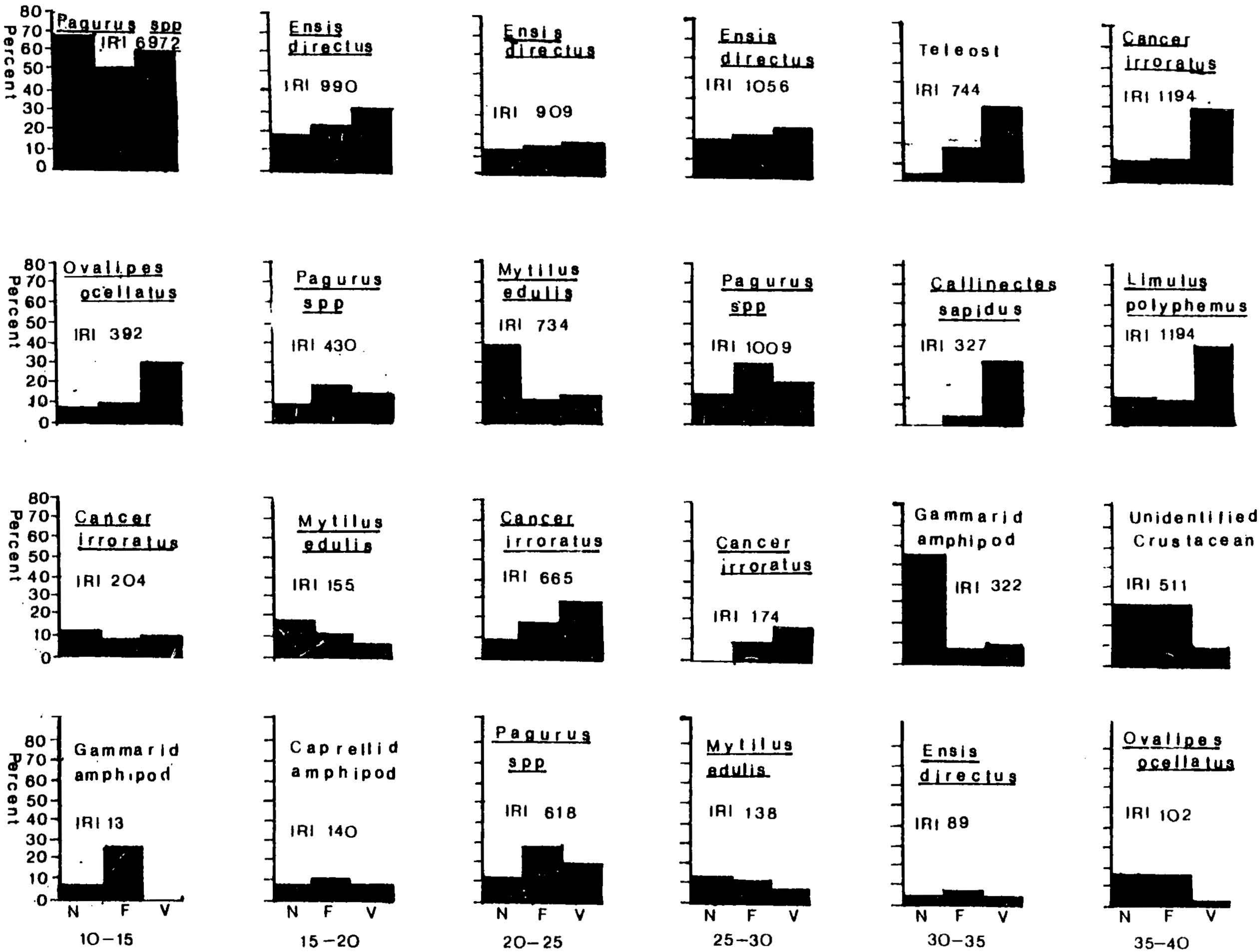
Hermit crabs were second ranking in IRI' (430), number (8.2%) and volume (15.5%); it ranked first in frequency (19.6%). Blue mussel was the third most important according to its IRI' value of 155. It had the largest number of individuals (16%), ranked third in frequency of occurrence (12.3%) and fifth in volume (5.5%).

According to the IRI', caprellid amphipod ranked fourth with a value of 140. Its importance is due mainly to its largest number of individuals and not frequency, which implies that it is an incidental food item. Rock crab with an IRI' of 107, ranked fifth in importance, consequently, it was not shown in Figure 4. But with a greater frequency (109%) and volume (7.2%) than the caprellids which had a frequency of 0.7% and volume of 3.7%, rock crab provided more food to a larger number of fish than the caprellids. Other food items included the mudcrab, _Panopeus herbstii_, calico crab and spider crab, _Libinia emarginata_.

Of the 163 black sea bass of size class 20-25 cm analyzed, 36 had empty stomachs (Table 12). The IRI' values were fairly close for the four most important food items (Fig. 3). The most importand food item, razor clam (IRI'=909) ranked second in number (19.7%), frequency (21.4%) and volume (22.1%). Blue mussel ranked second in IRI' (734) but ranked first in number (39.3%) and fourth in volume (13.9%)

Rock crab with an IRI' of 665 was third in importance. It was fifth in importance in number of individuals (8.1%), third in frequency (16.0%) and had the largest volume (27.6%).

Figure 4. Four predominant food items of the black sea bass in 5 cm. size classes by percent number (N), percent frequency (F), percent volume (V), and the modified Index of Relative Importance (IRI'). The IRI' are presented in decreasing order of importance from top to bottom.


Percent
0
10
20
30
40
50
60
70
80
Pagurus spp
IRI 6972
Ensis directus
IRI 990
Ensis directus
IRI 909
Ensis directus
IRI 1056
Teleost
IRI 744
Cancer irroratus
IRI 1194
Ovalipes ocellatus
IRI 392
Pagurus spp
IRI 430
Mytilus edulis
IRI 734
Pagurus spp
IRI 1009
Callinectes sapidus
IRI 327
Limulus polyphemus
IRI 1194
Cancer irroratus
IRI 204
Mytilus edulis
IRI 155
Cancer irroratus
IRI 665
Cancer irroratus
IRI 174
Gammarid amphipod
IRI 322
Unidentified Crustacean
IRI 511
Gammarid amphipod
IRI 13
Caprellid amphipod
IRI 140
Pagurus spp
IRI 618
Mytilus edulis
IRI 138
Ensis directus
IRI 89
Ovalipes ocellatus
IRI 102
N
F
V
10–15
15–20
20–25
25–30
30–35
35–40

Hermit crabs ranked fourth in importance (IRI'=618). They had the largest number (12%) and frequency (26.8%), while ranking third in volume (15.9%).

Unidentified teleosts were first noticed in this size class. With an IRI' of 37, it ranked fifth.

Of the 62 black sea bass analyzed from the size class 25-30 cm, 20 stomachs examined were empty (Fig. 4, Table 13). Razor clams ranked first with an IRI' of 1056. It ranked second in number (20%) and frequency (21.4%) and ranked first in volume (25.5%). Hermit crabs, the second ranking food item, also had a large IRI' of 1009. Hermit crabs ranked second in number (14.2%), and ranked first in frequency (28.5%) and volume (23.5%). Rock crabs, the third ranking food item had an IRI' of 174. It had the fifth largest number of individuals (2.6%), fourth in frequency (7.1%) and had the third largest volume (17.5%). Blue mussels with fourth largest IRI' (138) was fourth in number (13.1%), third in frequency (12.5%) and fifth in volume (5.4%). Calico crab was also important with an IRI' of 61. The greatest number of individual found were gammarid amphipods (40%), but its small volume and frequency kept its IRI' value low (19). A single unidentified teleost was also noticed in this size class.

Five empty stomachs were found among the 13 black sea bass of size class 30-35 cm examined. Unidentified teleosts were the most important food item (IRI'=938). Although ranking only third in the number of individuals (7.0%), unidentified teleosts had one of the greatest frequency (15.4%) and the largest volume (41.9%). A single blue crab, *Callinectes sapidus*, was found with the second largest volume (34.6%). It ranked second in the IRI' (327).

The gammarid amphipods had the largest number of individuals (54.4%) but had a small volume (5.2%) and a low frequency of 7.7%. These components yielded an IRI' of 322.25, making it the third most important food item. Razor clams ranked fourth in importance (IRI'=89.7); however, it was found in only one fish. Blue mussel was also eaten by fish of this size class as was the hydrozoan, Tubularia crocea.

Eight black sea bass of size class 35-40 cm were analyzed with two empty stomachs found (Table 14). Food items included two unidentified crustaceans. The other food items were ranked according to their volume, since their number and frequency were similar. Cancer irroratus and Limulus polyphemus had similar volume thus the same IRI' of 1194. Ovalipes ocellatus with a larger volume than Penaeus aztecus had an IRI' of 102.3, while the latter had an IRI' value of 75.1.

Only three black sea bass were collected from the size class 40-65 cm (Table 15). One was between 40 and 45 cm, another was 50-55 cm and the last between 60-65 cm. Two Cancer irroratus were found in the two smaller fish while an unidentified crustacean was found in the larger fish.

Direct Observations of Artificial Reef

Seasonal changes and recolonization occurred in the epifauna community associated with the reef between August and May. In August, 20-30% of the total surface area of ST 1 was encrusted with blue mussel, Mytilus edulis. Small clumps of coral, Astrangae danae, and barnacle, Balanus spp. were also present. The starfish, Asteria forbesi, was observed preying heavily on mussels in August. Hermit crabs, mudcrabs, rock crabs, and gammarid and caprellid amphipods were abundant within the mussel colony. By September, most of the blue mussels had been removed and only empty shells were found on the reef in December. The aforementioned crabs were observed only in August. Gammarid amphipods were still present among the empty mussel shells after August.

The hydroid, Tubularia crocea, was first noted in January, and increased until 80% of the total surface area was covered (March). The number of coral colonies also increased. Re-population of the blue mussel had occurred by April when they covered 90% of the reef and were growing among the hydroids. Large numbers of the gammarid amphipod (Melita dentata) and caprellids, Caprella geometrica, Aeginella longicoris and Caprella linearis were associated with the hydroid-mussel colony.

Almost the entire surface of the reef was covered by mussels in May. The Caprellids, Caprella penantis, Caprella equilibra and gammarid, Melita dentata were also abundant.

Black sea bass and pinfish on the artificial reef had seasonal pulses in abundance which followed water temperature changes.

Seven hundred black sea bass were estimated on ST 1 in August 1975 (Table 16). They were seen throughout the artificial reef structures, but higher concentrations were evident around features such as the wheelhouse and engine room of the landing-craft. Small black sea bass were usually moving about the reef structure and swam up to divers, while the larger sea bass were more reclusive. Tautogs were present on the reef all year round, with recruitment occurring in winter.

In November, 750 black sea bass were estimated on ST 1 and 450 were estimated in December. Black sea bass were also seen in the surrounding area unassociated with any reef structures. No black sea bass were observed at the artificial reef in dives during January and February. On a dive at the Chesapeake Light Tower in January, no black sea bass were observed but blue mussels covered 60% of the total surface area and were abundant on structures five meters from the bottom. An offshore artificial reef ("Triangle Reef"), located 30 km due east of Cape Henry in 34 meters of water, was also observed in February. The bottom temperature was 9.2°C, 2°C warmer than at ST 1 during February. Twenty-eight black sea bass were observed on an aircraft approximately 6 meters in length. Black sea bass were again abundant at ST 1 when the water warmed at 8.61°C in March. Thereafter, increasing numbers of black sea bass were seen on ST 1; 25 in April and 575 in May. Black sea bass were observed feeding on the coral present on the reef. In May the fish appeared to be in spawning condition: gravid gonad condition was confirmed during the dissection for food analysis.

Black sea bass are diurnal feeders. Diving observations were made at around midday and on one occasion black sea bass were observed to be feeding on the artificial reef.

Trawl Catch

Trawling catches in December and May (Table 17) near the artificial reef yielded invertebrates of the same species identified in the stomachs of black sea bass caught at the artificial reef. Razor clam, hermit crabs and rock crab were four invertebrate food types found in the December trawl that were especially important food items for the black sea bass. Black sea bass were captured by trawling in December, demonstrating that they can be found unassociated with the artificial reef nearby.

In May, rock crab and hermit crab were taken by the trawl. Juvenile tongue sole, *Symphurus plagiusa*, and spot ed hake, *Urophycis regius*, were collected in the trawl and may constitute the unidentified teleost remains in the sea bass stomach.

DISCUSSION

Seasonal Food Resource and Feeding

The black sea bass could be characterized as an opportunistic carnivore. Seasonal food resource are reflected by the diet of the black sea bass on the artificial reef and the surrounding area, i.e., in August blue mussel was an important food item from the reef but was unimportant in the fish's diet from September to December. Food items from the vicinity of the artificial reef such as the razor clam became more important after August. The razor clam is a good item that can only be found off the reef since it is a burrowing bivalve. Other important food items such as the rock crab and hermit crab, were consumed while abundant on the reef in August. They were foraged from the surrounding area when their numbers declined in September. Trawls in December confirmed the presence of razor clams, rock crabs and hermit crabs in the surrounding area.

Black sea bass remained on the reef after depletion of food resource on the reef, suggesting that they are attracted by shelter. In observing an artificial reef off New Jersey, Ogren and O'Neill (1970) observed adult black sea bass occupying new reefs before an overlying food was available. The food source in the area surrounding the reef allowed the black sea bass to remain on the reef. The importance of a nearby food resource was witnessed by Randall (1963). He attributed the higher concentration of fish on an artificial than a nearby natural reef to the additional food around the artificial reef. Grunts (Pomadasyidae) which were abundant on the reef fed on the eelgrass surrounding the artificial reef. Russell (1975) observed that "periferal living" fish species feeding about the perifery of a reef made up the bulk of the reef fish biomass. Feeding on the reef and the adjacent bottom was observed by Ogren and O'Neill (1970) on an artificial reef off New York where the stomach contents of cod revealed food items from the reef as well as the adjacent bottom. In South Carolina, black sea bass fed on organisms associated with an artificial reef and to a lesser extent on burrowing organisms on adjacent sand bottom (Ogren and O'Neill, 1970). For artificial reef fish that depend on the surrounding area for food, there may be an optimum size for the reef (Russell, 1975) whereby a maximum standing crop of fish can be maintained. A number of small reefs would increase the periferal habitat over a larger reef. To maximize the benefits of the Chesapeake Light Tower artificial reef, I recommend future and further construction of the reef be over a wider area. This would provide the black sea bass with a greater surrounding area for exploitation of food resource.

Size Class Food and Feeding

Black sea bass on the artificial reef showed a size-related feeding. Smaller fish fed primarily on crustaceans, while larger fish incorporated molluscs and other fish in their diet. The diet of black sea bass on the reef, regardless of size class, includes food items from the reef as well as the surrounding water area.

Seasonal Migration

Seasonal migration of the black sea bass was demonstrated in this study. In warmer waters off South Carolina (Cupka, 1972) and Florida (Beaumariage, 1964; Beaumariage and Wittich, 1966; and Beaumariage, 1969)

C. Striata are essentially non-migrating. Off Virginia, they migrate offshore when water temperature falls below 7.8°C (Pearson, 1932; Nesbit and Neville, 1935). Musick and Mercer (1977) showed that black sea bass in the Mid-Atlantic Bight (Cape Cod, Massachusetts to Cape Hatteras, North Carolina) move offshore and to the south in winter. The disappearance of the black sea bass from the artificial reef in winter suggest that they follow the migration pattern described by Musick and Mercer (1977).

The absence of black sea bass from the artificial reef in January, February and March and the presence of the fish in April and May appear to be correlated with temperature. Winter temperature at the artificial reef was 7.2°C while the lower limit of preference by black sea bass is 7.8°C (Nesbit and Neville, 1935). An artificial reef in deeper and warmer (9.4°C) water ("Triangle Reef") had black sea bass present in January and February. The presence of the black sea bass at the deeper and warmer artificial implys that the lower temperatures caused the migration from the more inshore artificial reefs utilized in this study. The offshore artificial reefs comprise a number of liberty ships and is a site of active reef expansion (Meier, Virginia Marine Resource Commission, personal communication). These offshore artificial reefs are likely to be an important wintering ground for the black sea bass and are used for commercial and recreational fishing.

Predation and Recruitment on Artificial Reef

The artificial reef could be described as in its climax state and seasonal succession is apparent. The seasonal succession of blue mussels and hydroid is probably caused by predation of the blue mussel by fishes and starfish. When blue mussel were abundant on the reef they were important food items for black sea bass, tautogs and pinfish.

The removal of blue mussel in the fall was accompanied by settlement of hydroids on the reef. Recruitment of mussel among the hydroids occurred in spring, completing the seasonal succession.

The mussel larvae that settled on the artificial reef in spring may have come from the mussels on the Chesapeake Light Tower. The survival of the mussels at the Chesapeake Light Tower could be due to the absence of tautogs (Chee, unpublished) and the fact that the upper parts of the structure is not subjected to predation by bottom feeding fishes. The recruitment of mussels is a vital aspect of the feeding ecology not only to black sea bass but to other fishes as well. Coustalin (1971) described a "dispenser feeder" which prevents predators from destroying a specific stock of animals on artificial reefs and thereby allows the "excess" to be eaten. The results of this research does not show conclusively that the surviving mussels on the Chesapeake Light Tower provided the larvae recruitment on the artificial reef in spring. But on artificial reefs where recruitment of food resource is dependent upon a nearby surviving stock of adults, "dispenser feeders" could be used to prevent total elimination of important invertebrates.

Topics for Further Research

Several aspects of the artificial reef should be further investigated as a result of observations made from this study. Movement of the black sea bass remains unclear. A tagging investigation could be carried to determine the movement of black sea bass on the artificial reef. Movement between reef structure and the surrounding area as well as movement to offshore reef could be investigated.

The three most abundant fish on the artificial reef, the black sea bass, the tautog and the pinfish all feed on the blue mussel on the reef.

This is an opportunity to study the interspecific competition for the food resource among these three fish.

The artificial reef is also an area to study the spawning behaviour of the black sea bass. Spawning condition of the black sea bass collected in May suggest that June and July would be the best time to observe if black sea bass spawn on the artificial reef and the spawning behaviour if spawning does occur on the reef.

CONCLUSION

The food and feeding of the black sea bass on the artificial reef show that it is an opportunistic carnivore that feed on the reef as well as the surrounding area.

There was a seasonal succession of food resource on the artificial reef. The seasonal succession of food resource was reflected in the diet of the black sea bass.

Seasonal migration of black sea bass occurred on the artificial reef. In winter, the black sea bass migrate away from the reef, probably to warmer waters offshore and to the south. Black sea bass can be found on the reef again in spring.

There was a size-related feeding of black sea bass on the reef. Smaller fish fed on crustaceans while larger fish shifted to molluscs and to fish. Food items of the different size classes of the black sea bass collected could be found on the reef and the adjacent area.

LITERATURE CITED

Beaumariage, D.S., 1964, Results from the 1963 Schlitz tagging program. Fla. Bd. Conserv. Mar. Lab., Tech. Ser. No. 43, 33 pp.

_______________, 1969, Returns from the 1965 Schlitz tagging program. Fla. Bd. Conserv. Mar. Res. Lab., Tech. Ser. No. 59, 38pp.

Beaumariage, D.S. and A.C. Wittich, 1966, Returns from the 1964 Schlitz tagging program. Fla. Bd. Conserv. Mar. Lab., Tech. Ser. No. 47, 50pp.

Bigelow, H.B. and W.C. Schroeder, 1963, Fishes of the Gulf of Maine. 1st. revision. U.S. Fish Wildl. Serv. Fish Bull. 74, 577pp.

Chee, P.K., Ichthyofauna of the Chesapeake Light Tower, Unpub. Manuscript, 26pp.

Coustalin, J.B., 1972, Methodologie experimentale en vue de la creastion des recifs artificiels. Tethys 3:827-840.

Cupka, D.M., R.K. Dias, and J. Tucker, 1973, Aspects of the fishery for and Biology of <u>Centropristes striata</u> in South Carolina waters. S.C. Dep. Wildl. Resour. Annu. Rep. Proj. 2-138-R01, 64pp.

Klima, E.F. and D.A. Wickham, 1971, Attraction of coastal pelagic fishes with artificial structures. Trans. Amer. Fish. Soc. 100:86-99.

Lagler, K.F., 1956, Freshwater fishery biology. Wm. C. Brown Company Publishers. Dubuque, Iowa (Second Edition), 421pp.

Matthews, H.H., 1966, Primary production measurements on an artificial reef. Master's thesis, Florida State University, 34pp.

McVey, J.P., 1970, Fishery ecology of the Pokai Artificial Reef. Ph.D. Dissertation. University of Hawaii, 284pp.

Miller, R.J., 1959, A review of the seabasses of the genus Centropristes (Serranidae). Tulane Stud. Zool. 7(2);35-68.

Musick, J.A., and Linda P. Mercer, 1977, Seasonal distribution of northern black sea bass, <u>Centropristes striata</u> (Pisces, Serranidae) in the Mid-Atlantic Bight with comments on the ecology and fisheries of the species. Trans. Amer. Fish Soc. 106:12-25.

Nesbit, R.A. and W.C. Neville, 1935, Conditions affecting the Southern winter trawl. Fishery Bull. U.S. Bur. Fish. Circ. No. 18, 12pp.

Ogren, L., and J. O'Neill, 1969, Ecology of fish populations of artificial reefs. Bureau of Sport Fisheries and Wildlife, pp. 187-189 (Resource publication 88).

Pearson, J. C., 1932, Winter trawl Fishery off the Virginia and North Carolina coasts. U.S. Bur. Fish., Invest. Rep. No. 10, 31pp.

Pinkas, L., M.S. Oliphant and I.L.K. Iverson, 1971, Food habits of Albacore, bluefin tuna, and bonito in California waters. California Fish and Game Bull. 152:1-105.

Randall, J.E., 1963. An analysis of the fish populations of artificial and natural reefs in the Virgin Island. Carribbean Jour. of Sci. 3:31-47.

Russell, B.C., 1975, The development and dynamics of a small artificial reef community. Helgolander Wiss. Meersunters 27:298-312.

Struhasaker, R., 1969, Demersal fish resources: composition, distribution and commercial potential of the continental shelf stocks off South-eastern United States. Fish Ind. Res., 4(7):261-300.

Table 1: Structures of artificial reefs where black sea bass were collected during this study. The water depth is 19.3 m.

ST 1: Consists of a landing-craft approximately 20 m in length and 6.1 m wide which projects three meters above the sea floor. A rectangular causeway, 27 m long and 7 m wide rests alongside the landing-craft. The causeway has vertical slits penetrating through the structure. This structure is 1.6 km due east of the Chesapeake Light Tower.

ST 2: Single landing-craft of similar dimensions as ST 1 and lies 1.2 km due east of ST 1. A spar buoy marks this structure.

ST 3: A single landing-craft of similar dimensions as ST 1, located 0.8 km due north of ST 1.

ST 4: Single wooden menhaden boat hull, located 0.18 km south of ST 2, approximately 21 m long and 6 m wide.

Table 2. Number of black sea bass captured according to size and month.

Month	10-15	15-20	20-25	25-30	30-35	35-40	40-45	50-55	60-65	TOTAL
Aug.*	3	69	66	33	4	1	1	1	1	179
Sept.	2	24	8	3						37
Oct.	3	11	3	2	1					20
Nov.*	14	92	52	12	5	4				179
Dec.	4	39	21	6	2					72
May	0	10	13	6	1	3				33
TOTAL	26	245	163	62	13	8	1	1	1	520

GRAND TOTAL

* Two sampling cruises during month.

Table 3. Number percent, volume percent, frequency percent and the IRI' of 520 black sea bass collected from an artificial reef off Virginia.

Food Items	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	73	7	152.5	26.2	49	15.9	601
Ovalipes ocellatus	10	1.0	15.1	2.6	9	2.9	10
Callinectes sapidus	1	0.1	10	1.7	1	0.3	0
Panopeus herbstii	7	0.7	6.3	1.0	5	1.6	2
Unidentified xanthid crab	1	0.1	1.5	0.2	1	0.3	0
Lobinia emarginata	3	0.3	0.9	0.1	1	0.3	0
unidentified spider crab	1	0.1	0.9	0.1	1	0.3	0
Pagurus spp.	132	12.7	106.2	18.2	84	27.3	729
Penaeus aztecus	3	0.3	7.8	1.3	3	1.0	1
Caprellidea	169	16	6.0	0.4	2	0.6	17
Ostracoda	1	0.1	tr.	1.0	1	0.3	0
Squilla empusa	1	0.1	8.9	1.5	1	0.3	0
Balanus spp.	1	0.1	0.3	0.1	1	0.3	0

Continued...

Table 3: continued

Food Items	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Cl. Arachnoidea							
Limulus polyphemus	4	0.4	47	1.06	4	1.3	1.74
Phylum Mollusca							
Class Bivalvia							
Mytilus edulis	317	30.5	38.24	6.6	57	18.5	322
Modiolus modiolus	1	0.1	10.5	1.8	1	0.3	1.0
Ensis directus	167	16.0	146.1	25.2	62	20.1	910
Mercenaria mercenaria	2	0.2	1.0	0.17	2	0.7	0
Solemya velum	1	0.1	1.0	0.17	1	0.3	0
Class Gastropoda							
Crepidula fornicata	1	0.1	0.6	0.1	1	0.3	0
Class Cephalopoda							
Loligo peali	1	0.1	4.0	0.7	1	0.3	0
Phylum Echinodermata							
Class Echinoida							
Arbacia punctulata	8	0.8	1.7	0.3	5	1.6	1.0
Phylum Vertebrata							
Cl. Osteichthyes	18	1.6	11.8	2.03	5	1.6	7.0
Fam. Gobiidae	1	0.1	0.4	0.7	1	0.3	3.0

Table 4. Number percent, volume percent, frequency percent and the IRI' of 179 black sea bass collected in August 1975.

Food Items	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	33	7.8	130.1	35.2	33	19.1	947
Panopeus herbstii	4	0.9	3.3	0.9	3	1.7	2
Libinia emarginata	2	0.5	6.5	1.8	1	0.6	1
Pagurus spp.	61	14.5	59.7	16.2	39	22.6	598
Penaeus aztecus	1	0.2	3.2	0.9	1	0.6	0
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	185	43.8	31.1	8.4	44	25.5	583
Ensis directus	95	22.5	79.5	21.5	26	15.1	807
Mercenaria mercenaria	1	0.2	1	0.3	1	0.6	0
Cl. Gastropoda							
Crepidula fornicata	1	0.2	0.6	0.2	1	0.6	0
Phylum Echinodermata							
Cl. Echnoida							
Arbacia punctulata	7	1.7	0.7	0.2	4	2.3	0

Continued...

Table 4: continued

Food Items	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Vertebrata							
Cl. Osteichthyes	14	3.3	37	10	2	1.2	44
Unidentified	18	4.3	17.1	4.6	18	10.4	67

Table 5. Number percent, volume percent, frequency percent and the IRI' of 37 black sea bass collected in September 1975.

Food Items	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda Cl. Crustacea							
Cancer irroratus	3	3.0	0.6	3	3	9.1	36
Pagurus spp.	14	14.0	7.2	36	10	30	1594
Ostracoda	1	1.0	traces	--	1	3.	4
Gammaridea	63	63.0	0.7	3.5	1	3.0	231
Subcl. Cirripedia *Balanus spp.*	1	1.0	0.3	1.5	1	3	6
Phylum Mollusca Cl. Bivalvia							
Ensis Directus	8	8.0	5.9	29.3	7	21.2	854
Mytilus edulis	6	6.0	traces	--	6	18.2	24
Phylum Vertebrata Cl. Osteichthyes	1	1.0	0.9	4.5	1	3	13
Unidentified	3	3.0	4.5	22.3	3	9	269

Table 6. Number percent, volume percent, frequency percent and the IRI' of 20 black sea bass collected in October 1975.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	3	33.3	1.9	13.9	2	25	742
Pagurus spp.	1	11.1	0.7	5.1	1	12.5	108
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	1	11.1	traces		1	12.5	23
Modiolus modiolus	1	11.1	10.5	76.9	1	12.5	1816
Unidentified	3	33.3	0.55	4.0	3	37.5	285

Table 7. Number percent, volume percent, frequency percent and IRI' of 179 black sea bass collected in November 1975.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	9	6.3	4.7	2.9	7	7.7	41
Ovalipes oscellatus	2	1.4	7	4.4	2	2.2	15
Calinectes sapidus	1	0.7	10	6.3	1	1.1	11
Xanthid crab	1	0.7	1.5	1.0	1	1.1	1
Spider crab	1	0.7	0.9	0.6	1	1.1	1
Pagurus spp.	44	30.6	25.9	16.4	25	27.5	953
Cl. Arachnoidea							
Limulus polyphemus	4	2.8	47	29.7	4	4.4	213
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	12	8.3	traces	--	2	2.2	10
Ensis directus	42	29.2	38.5	24.3	20	21.9	1244
Mercenaria mercenaria	1	0.7	0.2	0.1	1	1.1	0
Solemya velum	1	0.7	1	0.6	1	1.1	1
Phylum Echinodermata							
Cl. Echinoida							
Arbacia punctulata	1	0.7	1.0	0.6	1	1.10	1

Continued...

Table 7: continued

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Vertebrata							
Cl. Osteichthyes	4	2.8	2.1	1.3	4	4.4	9
Unidentified	19	13.2	13.7	8.7	19	20.9	295

Table 8. Number percent, volume percent, frequency percent and IRI' of 72 black sea bass collected in December 1975.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	3	2.1	0.9	2.0	2	7.0	18
Ovalipes ocellatus	3	2.1	9.1	18.4	7	24.1	482
Libinia emarginata	1	0.7	2.0	4.5	1	3.5	18
Pagurus spp.	8	5.7	5.3	12.0	7	24.1	358
Squilla empusa	1	0.7	8.9	20.2	1	3.5	84
Gammaridea	101	72.1	2.0	4.6	2	6.9	358
Phylum Mollusca							
Cl. Bivalvia							
Ensis directus	15	10.7	8.9	20.2	1	3.5	285
Mytilus edulis	1	0.7	0.2	0.5	1	3.5	1
Phylum Vertebrata							
Cl. Osteichthyes	1	0.7	5.0	11	1	3.5	47
Gobiidae	1	0.7	0.4	0.9	1	3.5	3
Unidentified	5	3.6	2.4	5.4	4	17	113

Table 9. Number percent, volume percent, frequency percent and IRI' of 33 black sea bass collected in May 1976.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	3	0.9	6.1	15.6	2	8.7	150
Panopeus herbstii	3	0.9	3.0	7.7	2	8.7	73
Pagurus spp.	4	1.3	7.2	18.4	4	17.4	342
Melita dentata	12	3.8	0.2	0.5	1	4.4	4
Caprellidea	169	53.1	6.0	15.3	2	8.7	946
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	112	35.2	6.9	17.6	3	13.0	349
Ensis directus	7	2.2	1.2	3.1	1	4.4	20
Phylum Cephalopoda							
Loligo peali	1	0.3	4.0	10.2	1	4.4	47
Phylum Vertebrata							
Cl. Osteichthyes	1	0.3	1.0	2.6	1	4.4	11
Unidentified	6	1.9	3.6	9.2	6.	26.1	256

Table 10. Number percent, volume percent, frequency percent and IRI' of 26 black sea bass of size class 10-15 cm.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	2	11.1	1.1	10.5	1	8.3	204
Ovalipes ocellatus	1	5.6	3.0	28.3	1	8.3	392
Pagurus spp.	12	66.7	6.4	59.8	6	50	6975
Gammaridea	1	5.6	traces	--	1	8.3	13
Unidentified	2	11.1	0.2	1.4	3	25	50

Table 11. Number percent, volume percent, frequency percent and IRI of 245 black sea bass of size class 15-20 cm.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	24	5.5	11.5	7.2	13	109	107
Ovalipes ocellatus	3	0.7	9.0	5.6	3	2.2	16
Panopeus herbstii	6	1.4	5.6	3.5	6	4.4	19
Libinia emarginata	4	0.9	7.9	4.9	3	2.3	15
Pagurus spp.	36	8.2	24.9	15.5	27	19.6	430
Penaeus aztecus	2	0.5	3.6	2.2	2	1.5	4
Melita dentata	12	2.8	0.2	0.1	1	0.7	0
Caprellidea	162	37.0	6	3.7	1	0.7	140
Ostracoda	1	0.2	traces	--	1	0.7	0
Phylum Mollusca							
Cl. Bivalvia	73	16.7	8.9	5.5	17	12.3	155
Ensis directus	67	15.3	48.7	30.3	24	17.4	990
Solemya velum	1	0.2	1.0	0.6	1	0.7	0.
Mercenaria mercenaria	1	0.2	0.8	0.5	1	0.7	0
Cl. Gastropoda							
Crepidula fornicata	1	0.2	0.6	0.4	1	0.7	0

Table 11: continued

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Echinodermata							
Cl. Echinoida							
Arbacia punctulata	10	2.3	1.9	1.2	2	1.2	4
Cl. Holothuroidea	1	0.2	11.7	7.3	1	0.7	6
Unidentified	27	6.2	15.26	9.5	27	19.6	244

Table 12. Number percent, volume percent, frequency percent and IRI' of 163 black sea bass of size class 20-25 cm.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	28	8.1	72.5	27.6	18	16.1	665
Panopeus herbstii	2	0.6	2.7	1.0	1	0.9	1
Pagurus spp.	42	12.1	41.8	15.9	30	26.8	618
Squilla empusa	1	0.3	8.9	3.4	1	0.9	4
Gammaridea	45	13	2.0	0.8	1	0.9	10
Cl. Arachnoidea							
Limulus polyphemus	2	0.6	9.8	3.7	2	1.8	8
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	136	39.3	36.6	13.9	15	13.9	734
Ensis directus	68	19.7	58.2	22.1	24	21.4	909
Cl. Cephalopoda							
Loligo peali	1	0.3	4.0	1.5	1	0.9	1
Phylum Echinodermata							
Cl. Echinoida							
Arbacia punctulata	2	0.6	0.4	0.1	1	0.9	0

Continued...

Table 12: continued

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Vertebrata							
Cl. Osteichthyes	6	1.7	16.1	6.1	5	4.5	37
Gobiidae	1	0.6	0.4	0.2	1	0.9	0
Unidentified	12	3.5	9.7	3.7	12	10.7	52

Table 13. Number percent, volume percent, frequency percent and IRI' of 52 black sea bass of size class 25-30 cm.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	5	2.9	19.1	17.5	4	7.1	174
Ovalipes ocellatus	4	2.3	8.8	8.0	3	5.4	61
Libinia emarginata	1	0.6	2.0	1.8	1	1.8	4
Pagurus spp.	25	14.3	25.8	23.6	16	28.6	1009
Gammaridea	70	40	0.5	0.5	1	1.8	19
Balanus spp.	1	0.6	0.3	0.3	1	1.8	0
Cl. Arachnoidae							
Limulus polyphemus	2	1.1	9.0	8.2	2	3.6	38
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	23	13.1	5.9	5.4	7	12.5	138
Ensis directus	35	20	27.9	25.5	12	21.4	1056
Phylum Echinodermata							
Cl. Echinoida							
Arabacia punctulata	2	1.1	0.4	0.3	1	1.8	0
Phylum Vertebrata							
Cl. Osteicthyes	1	0.6	5.0	4.6	1	1.8	10

Table 13: continued

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Cnidaria							
Cl. Hydrozoa							
Tubularia crocea	traces						
Unidentified	6	3.4	4.8	4	1	10	56

Table 14. Number percent, volume percent, frequency percent and IRI' of 13 black sea bass of size class 30-35 cm.

Food Item	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	2	3.5	0.9	3.08	2	15.4	88
Callinectes sapidus	1	1.8	10	34.6	1	7.0	327
Pagurus spp.	1	1.8	0.5	1.6	1	7.0	11
G Gammaridea	31	54.4	1.5	5.2	1	7.0	322
Phylum Mollusca							
Cl. Bivalvia							
Mytilus edulis	3	5.3	0.3	0.9	2	15.4	17
Ensis directus	3	5.3	2.0	6.9	1	7.7	89
Mercenaria mercenaria	1	1.8	0.2	0.7	1	7.7	6
Phylum Cnidaria							
Cl. Hydrozoa							
Tubularia crocea	10	17.5	0.5	1.7	1	7.7	43
Phylum Vertebrata							
Cl. Osteicthyes	4	7.0	12.1	41.9	2	15.4	938
Unidentified	1	1.8	1.0	3.5	1	7.76	32

Table 15. Number percent, volume percent, frequency percent and IRI' of 8 black sea bass of size class 35-40 cm, and three of size class 40-65 cm.

Food Items	Number	Number Percent	Volume (mls)	Volume Percent	Frequency	Frequency Percent	IRI'
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	1	14.3	35	41.8	1	14.3	1194
Ovalipes ocellatus	1	14.3	3.0	3.6	1	14.3	102
Penaeus aztecus	1	14.3	2.2	2.6	1	14.3	75
Cl. Arachnoidea							
Limulus polyphemus	1	14.3	35	41.8	1	14.3	1194
Unidentified Crustacean	2	28.6	7.5	9.0	2	28.6	511
Unidentified	1	14.3	1.0	1.2	1	14.3	34
Size Classes 40-65:							
Phylum Arthropoda							
Cl. Crustacea							
Cancer irroratus	2		16.5		2		
Unidentified crustacean	1		traces		1		

Table 16. Monthly bottom temperature and visual estimate of fishes on artificial reef structure ST 1.

	A	S	O	N	D	J	F	M	A	M
Temperature (^{o}C)	18.88	21.11	20.1	18.3	13.9	6.67	7.2	8.61	8.65	11.1
Fish species										
Black sea bass *Centropristis striata*	700	*	*	750	500	0	0	17	25	575
Tautogs *Tautoga onitis*	30	*	*	60	150	35	30	30	40	34
Pinfish *Lagodon rhomboides*	735	*	*	600	0	0	0	0	0	0
Conger eel *Conger conger*	1	*	*	1	1	0	0	0	0	0
Lingcod *Urophycis regius*	1	*	*	3	0	0	0	0	0	0
Blenny *Hypsoblennius hentz*	0	*	*	16	0	0	0	0	0	0
Amberjack *Seriola dumerulii*	0	*	*	20	0	0	0	0	0	0
Scads *Decapterus spp.*	0	*	*	55	0	0	0	0	0	0
Cunner *Tautogolabrus adspersus*	0	*	*	3	0	0	0	0	0	0

*Unable to carry out fish count because of poor visibility.

Table 17. Checklist of organisms collected by otter trawl near the artificial reef in December 1975 and May 1976.

December, 1975

Phylum Arthropoda
Cl. Crustacea
Or. Decapoda
Infraor. Brachyura
Fam. Cancridae
Cancer irroratus

Fam. Portunidae
Ovalipes ocellatus

Fam. Xanthidae
Neopanope texana sayi

Infraor. Anomura
Pagurus longicarpus
Pagurus pollicaris
Suborder Natantia
Penaeus aztecus

Phylum Mollusca
Cl. Bivalvia
Fam. Solenidae
Ensis directus

Cl. Cephalopoda
Or. Teuthaidea
Loliguncula brevis

Phylum Vertebrata
Cl. Osteichthyes
Fam. Cynoglossidae
Symphurus plagiusa

Fam. Gadidae
Urophycis regius

Fam. Ammodytidae
Ammodytes americanus

Fam. Serranidae
Centropristis striata

Fam. Merluccidae
Merluccius bilinearis

May, 1976

Phylum Arthropoda
Cl. Crustacea
Or. Decapoda
Infraor. Brachyura
Fam. Cancaridae
Cancer irroratus

Infraor. Anomura
Pagurus longicarpus
Pagurus pollicaris

Infraor. Caridea
Fam. Crangonidae
Crangon septemspinosa

Phylum Mollusca
Cl. Cephalopoda
Or. Teuthida
Loliguncula brevis

Phylum Vertebrata
Cl. Osteichthyes
Fam. Carangidae
Trachinotus carolinus

Fam. Triglidae
Prionotus carolinus

Fam. Cynoglossidae
Sympurus plagiusa

Fam. Gadidae
Urophycis regius